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Method for Determining an Exhaust Gas Recirculation Quantity for an Internal Combustion Engine Having Exhaust Gas Recirculation

This invention relates to a method for determining an exhaust gas recirculation quantity for an internal combustion engine having exhaust gas recirculation. Such internal combustion engines are used as drive motors for motor vehicles, for example. Exhaust gas recirculation is known to offer advantages with regard to fuel consumption and exhaust emissions. The term "quantity" is used for the sake of simplicity in the present case to denote a physical variable indicative of quantity, e.g., the mass or the quantity rate or mass flow rate of recirculated exhaust gas and/or gas mixture fed into the internal combustion engine.

The quantity of fresh gas fed into the combustion chamber(s) of an internal combustion engine may be measured, for example, via a hot-film air-mass meter (HFM) in a respective intake manifold and/or intake tract. The exhaust gas recirculation quantity cannot be determined in this way and is therefore determined and known indirectly at most for a very specific design state, e.g., a normal state of an internal combustion engine without any additional measures. For other engine operating states and in particular for changing temperatures and changing atmospheric pressure of the environment from which the fresh gas and/or fresh air for the motor is obtained, efforts should be made to establish a modified exhaust gas recirculation rate in comparison with the design state, i.e., the normal state,

in order to be able to comply accurately with emission limits, for example. Therefore there is a need to know exactly the exhaust gas recirculation rate at all points in time in order to be able to regulate it at a suitable level.

Unexamined German Patent DE 199 34 508 A1 describes a method for controlling the exhaust gas recirculation, wherein a setpoint exhaust gas recirculation rate is determined on the basis of the engine load, engine torque and air pressure; an actual exhaust gas recirculation rate and the opening and closing movements of a throttle valve are detected by sensors, and an exhaust gas recirculation control valve is operated as a function of the difference between the actual and setpoint exhaust gas recirculation rates as well as a throttle valve opening signal, a throttle valve closing signal and the respective air pressure. The exhaust gas recirculation quantity is determined by sensors based on a measurement of the pressure difference at a throttle opening provided in a respective exhaust gas recirculation line.

The object of the present invention is to provide a method of the type defined in the preamble to permit precise and reliable determination of the exhaust gas recirculation quantity with little effort, in particular at various operating states.

The present invention achieves this object by providing a method for determining the exhaust gas recirculation quantity with the features of Claim 1. In this method, the exhaust gas recirculation quantity is determined from an exhaust gas temperature, a fresh gas temperature, a fresh gas quantity and/or a volumetric efficiency. The fresh gas temperature is determined by a fresh gas temperature model which is adaptively adjusted while the engine is running, adapting it to relevant influencing parameters

pertaining to the fresh gas temperature. Volumetric efficiency is a measure of the fresh gaseous supply [air] to the engine. It is defined as the ratio of the total quantity of gas supplied to the engine per operating cycle to the theoretical load, i.e., filling per operating cycle, i.e., to the theoretical fresh load in filling the geometric cubic capacity of the engine with air and/or mixture in the ambient state when the engine is not supercharged and/or in the state downstream from a compressor and/or a charge air cooler that is provided in an internal combustion engine with supercharging. For operation with exhaust gas recirculation, volumetric efficiency is defined as the ratio of the total quantity of gas mixture supplied per operating cycle to the quantity of gas mixture in filling the geometric cubic capacity of the internal combustion engine with gas mixture in the state after admixture through the exhaust gas recirculation. Volumetric efficiency is also referred to as absorption capacity.

The exhaust gas temperature, a temperature of the recirculated exhaust gas, also known as the exhaust gas recirculation temperature, and the volumetric efficiency are preferably also determined by corresponding models. These models are adaptable to relevant influencing parameters pertaining to the respective quantities. The models and/or overall models preferably each comprise a basic model, a correction model and/or a filter block. With the basic model, a basic value is determined for the output variable and/or for a part of the output variable of the corresponding overall model. This basic value is corrected, if necessary, by an output variable of the correction model if certain input variables that are relevant for the output variable of the overall model deviate from predefined reference values and/or reference states. When speaking of a correction model, this in fact refers to a

group of correction models having one correction model per input variable. For the determination of deviations, the input variables are monitored, preferably by measurement and subsequent comparison with the reference values. The basic models and/or correction models are preferably engine characteristic maps and/or characteristic lines, but they may also be linear and/or nonlinear mathematical and/or physical simulation models based on differential equations. The basic models and/or correction models may also be neural networks.

Each of the overall models preferably also has a filter block. The filter blocks are preferably first-order delay elements, so-called PT1 elements. However, other filters, preferably dynamic filters, may also be used, such as delay elements of a higher order or delay elements in combination with monostable elements. By means of filtering, a dynamic response is imposed upon an input variable of a filter block, so that a (calculated) output variable of the filter block approximates the real response of the measured equivalent of the output variable. Such filtered variables, i.e., variables determined by filtering, can be adjusted and/or regulated more easily by a regulating and/or controlling means. This is the case with the exhaust gas recirculation rate in particular. It is regulated more rapidly and has less overshooting, which leads to a lower component burden and to more steady emissions, thus preventing emission peaks. Filtering of variables is also known as dynamic correction.

The inventive method can be integrated to advantage into a control unit, e.g., in an engine control unit and/or a vehicle control unit conventionally present in a motor vehicle, for example. With the inventive

method, the prevailing exhaust gas recirculation quantity, i.e., exhaust gas recirculation rate can be calculated with a high precision under steady-state and non-steady-state conditions and under different operating conditions and ambient conditions.

The basic models and correction models are preferably determined in experiments or on a test stand, for example, preferably before market introduction of the internal combustion engine, and are stored in a memory of a control unit of the conventional type. The basic models and correction models are preferably only type-specific and are not determined in advance for each individual internal combustion engine in this way and then adapted to the individual engine during operation thereof.

The inventive method of determining the exhaust gas recirculation quantity does not require any sensors for measuring the exhaust gas recirculation quantity. Even without exhaust gas recirculation quantity sensors, the quantity of recirculated exhaust gas can be determined accurately and reliably. To do so, the models used are adapted by using certain correction models, so the inventive method is automatically adapted to changes occurring during the service life of the engine; such changes would include operating states that deviate from a basic state (e.g., non-steady-state processes, changes in ambient conditions).

Other advantageous embodiments of this invention are derived from the subclaims and the exemplary embodiments depicted below on the basis of the drawings.

FIG 1 shows a schematic diagram of an internal combustion engine having an intake tract and an exhaust tract,

FIG 2 shows a block diagram of the inventive method for determining the exhaust recirculation rate,

FIG 3 shows a block diagram of an overall model for determining a fresh gas temperature,

FIG 4 shows a block diagram of an overall model for determining an exhaust gas temperature,

FIG 5 shows a block diagram of an overall model for determining a temperature of the recirculated exhaust gas and

FIG 6 shows a block diagram of an overall model for determining a volumetric efficiency.

The same reference notation is used here to denote the same functional components and/or quantities. For the sake of simplicity, certain input variables of certain function blocks such as summing points, filter blocks, models are identified with u. Likewise, certain output variables of certain function blocks are indicated with y. The input variables and output variables have the reference notation of the corresponding function blocks as a subscript. If the input variables are reference values and/or reference states, also referred to as initial values and/or initial states, then these input variables have the numeral 0 as an additional subscript. If an input variable and/or an output variable stands for a group of input variables and/or output variables, respectively, then this input variable and/or output variable has

the letter i as an additional subscript. The input variables and/or output variables may of course also be state variables and/or states. If a function block is depicted as a rectangle having multiple rectangles staggered one behind the other, this is a depiction of a model comprising multiple individual models.

FIG 1 shows as an example a system in which the inventive method may be used for determining an exhaust gas recirculation rate. An intake pipe and/or an intake tract 4 for fresh gas and/or fresh air and an exhaust tract 5 are assigned to the internal combustion engine 1 having a driveshaft 2. A turbocharger 3 is provided in the intake tract 4 and in the exhaust tract 5; a compressor (not shown) of the exhaust gas turbocharger 3 is situated in the intake tract 4 and an exhaust turbine (not shown) of the turbocharger 3 is situated in the exhaust tract 5. An exhaust gas recirculation system 8 is provided between the internal combustion engine 1 and the exhaust gas turbocharger 3, connecting the exhaust gas tract 5 to the intake tract 4. Downstream from the turbocharger 3 and upstream from the connecting point (not indicated further) to the recirculation system 8, a charging air cooler 7 is preferably provided in the intake tract 4. It is used for cooling the fresh air. Another cooler 9 and an exhaust gas recirculation valve 10 are preferably provided in the recirculation system 8, with the exhaust gas recirculation valve preferably being situated downstream from the charging air cooler 9.

A quantity of fuel m_{fuel} is supplied to the internal combustion engine through a feed line (not shown). In addition, a quantity of fresh gas m_{air} is supplied to the internal combustion engine 1 through the intake tract 4. This

quantity of fresh gas m_{air} is measured by a sensor 6, e.g., a hot-film air-mass sensor (HFM). An exhaust gas quantity $m_{exhaust}$ is preferably sent through the exhaust tract 5 into an exhaust system of the type conventionally provided. The quantity of fresh gas is mixed with a quantity of exhaust recirculated through the recirculation system 8 at a measurement point (not indicated further here) and is supplied as the gas mixture quantity m_{mix} to the internal combustion engine 1.

The temperature T_{air1} and the pressure of the fresh gas are preferably determined at a measurement point 11 in the intake tract 4 which is preferably situated downstream from the charging air cooler 7 and upstream from the connecting point (not indicated further here) to the recirculation system 8. The temperature T_{air1} and the pressure are preferably determined by appropriate sensors and/or meters. In addition, variables that are also relevant for the inventive process include a fresh gas temperature T_{air2} at a point in the intake tract 4 directly upstream from the mixing point (not identified further here), i.e., at a point 12, for example, an exhaust temperature which corresponds to the temperature of the exhaust after leaving the internal combustion engine at a point 13 in the exhaust tract 5 and a temperature of the recirculated exhaust which corresponds to the temperature of the recirculated exhaust preferably directly prior to admixture in the exhaust tract 4. The method for determining the exhaust temperature and the temperature T_{Air2} is explained in greater detail below.

FIG 2 shows a block diagram of the inventive method for determining an exhaust gas recirculation quantity and/or an exhaust gas recirculation rate r_{AGR}. In a function block 14, an exhaust gas recirculation quantity and/or

an exhaust gas recirculation rate r_{AGR} is determined from a temperature of a recirculated exhaust gas T_{AGR}, hereinafter also referred to as the exhaust gas recirculation temperature, a fresh gas temperature and/or a charging air temperature directly before admixture of the added exhaust gas T_{air2}, a volumetric efficiency □ and other input variables u_{14i} that are relevant in particular to the exhaust gas quantity and/or rate, in particular the fresh air quantity m_{air} determined via the sensor 6; this is done by using a mass balance equation, a volumetric efficiency equation which is based on the ideal gas equation, and a mixing equation based on an energy balance equation. In addition, a mixed temperature can be determined from said variables and equations after admixture of the recirculated exhaust gas in the intake pipe 4 and the total cylinder mass and/or gas mixture quantity m_{mix} drawn in by the internal combustion engine. The exhaust gas recirculation quantity m_{AGR} is determined by subtracting the fresh gas component m_{air} from the total gas mixture quantity m_{mix}.

The fresh gas temperature directly before admixture of the recirculated exhaust gas T_{air2} is calculated by means of a fresh gas temperature model 15 from the fresh gas temperature T_{air1} at the measurement point 11 (see FIG 1) and additional input variables u_{15i} which are relevant for the fresh gas temperature. The exhaust gas recirculation temperature T_{AGR} is determined by means of an exhaust gas recirculation model 17 from input variables u_{17i} which are relevant to the exhaust gas recirculation temperature and from the exhaust gas temperature $T_{Exhaust}$, these in turn being determined by means of an exhaust gas temperature model 16 from input variables u_{16i} that are relevant to the exhaust gas temperature. The volumetric efficiency □ is determined by means of a volumetric efficiency model 18 from input variables

u_{18i} which are relevant to the volumetric efficiency. The models 15 through 18 are illustrated in detail in FIGS 3-6.

FIG 3 shows a block diagram of the overall model for determining the fresh gas temperature T_{air2} and/or the fresh gas temperature model 15, i.e., a block diagram of the fresh gas temperature model 15. In the fresh gas temperature model 15, a fresh gas temperature directly before admixture of the recirculated exhaust gas T_{air2} is determined from the fresh gas temperature T_{air1} at the measurement point 11 in FIG 1, the fresh gas mass flow dm_{air}/dt and additional input variables $u_{15.3i}$ that are relevant for the fresh gas temperature. The input variables u_{15i} of the function block 15 of FIG 2 comprise the fresh gas mass flow dm_{air}/dt and the input variables $u_{15.3i}$. The model 15 describes heating or cooling of the fresh air intake and/or the fresh gas intake from the temperature T_{air1} at the measurement point 11 up to a measurement point 12 directly prior to admixture of the recirculated exhaust gas in the intake tract 4. On the basis of the temperatures of various components, in particular the temperature of the internal combustion engine, there may be a significant heating, or in certain cases also a cooling effect, which must be taken into account in determining the exhaust gas recirculation rate. The mass fraction of the fresh air and/or the fresh gas is large in relation to the total quantity of gas mixture in comparison with the recirculated exhaust gas, so an accurate knowledge of the temperature of the fresh gas immediately before admixture of the recirculated exhaust gas is desirable. An inaccurate temperature of the fresh gas would result in a great distortion of the exhaust gas recirculation rate calculated in the function block 14 in FIG 2. The fresh gas temperature model 15 thus describes the phenomenology of a heating process and/or a cooling process.

A basic temperature change $y_{15.1}$ with a reference state and/or an initial state is determined from the fresh gas temperature T_{air1} and the fresh gas mass flow dm_{air}/dt in a basic model 15.1. The basic model 15.1 is preferably an engine characteristic map. In a correction model 15.3, a correction variable $y_{15.3i}$ for the change in the basic temperature $y_{15.3i}$ is determined from the fresh gas mass flow dm_{air}/dt and additional input variables $u_{15.3i}$. The deviation in the input variables $u_{15.3i}$ from these respective predefined reference input variables and/or reference states $u_{15.3i0}$ is taken into account here. This deviation is preferably defined as the difference between the input variables $u_{15.3i}$ and the reference input variables $u_{15.3i0}$ assigned to them. However, the deviation may also be defined as the quotient of the input variables $u_{15.3i}$ and the reference input variables $u_{15.3i0}$. The reference input variables $u_{15.3i0}$ may be entered into a field 15.4, which is preferably a memory area of a control unit.

The input variables $u_{15:3i}$ [sic; $u_{15.3i}$] and the reference states $u_{15.3i0}$ assigned to them preferably include a cooling water temperature of the internal combustion engine and/or an ambient temperature. The correction model 15.3 preferably involves a group of models for each input variable $u_{15.3i}$. Likewise, the correction value $y_{15.3i}$ is a vector and/or a group of correction values, namely a correction value $y_{15.3i}$ for each input variable $u_{15.3i}$.

At a coupling point 15.2, the correction value(s) $y_{15.3i}$ is (are) added to the basic temperature $y_{15.i}$. A multiplication may also be performed instead of a summation at the coupling point 15.2. A temperature change, not specified further here but already corrected, forms the output of the coupling point 15.2 and is sent to a filter 15.5, which is preferably a first-order delay

element. A dynamic output variable $y_{15.5}$ is formed from the static input variable by means of the filter 15.5. Thus there is a dynamic correction. Due to the filtering, the change in temperature preferably has a more fluid and thus more realistic course. At a coupling point 15.6, the filtered and corrected temperature change $y_{15.5}$ is added to the fresh gas temperature T_{air1} to form the fresh gas temperature immediately before admixture of the recirculated exhaust gas T_{air2}. Instead of a summation, a multiplication may also be performed at the coupling point 15.6.

FIG 4 shows a block diagram of the overall model for determining the exhaust gas temperature $T_{exhaust}$ and/or the exhaust gas temperature model 16. The exhaust gas temperature model 16 is determined from a fuel quantity m_{fuel}, a rotational speed n of the internal combustion engine and from additional input variables $u_{16.3i}$ that are relevant to the exhaust gas temperature $T_{exhaust}$. Then in a basic model 16.1, a basic temperature $y_{16.1}$, preferably static, is determined from the fuel quantity m_{fuel} and the rotational speed n. The input variables $u_{16.i}$ of the function block 16 in FIG 2 comprise the input variables $u_{16.3i}$, the rotational speed n and the fuel quantity m_{fuel}. Then a correction value $y_{16.3i}$ for the preferably static exhaust gas temperature $y_{16.1}$ is determined from the input variables $u_{16.3i}$ in a correction model 16.3. To do so, any deviation of the input variables $u_{16.3i}$ from predefined reference input variables and/or initial input variables $u_{16.3i0}$ assigned to them is taken into account in the correction model. This deviation is preferably defined as the difference between the input variables $u_{16.3i}$ and the reference input variables $u_{16.3i0}$. However, it may also be defined as the quotient of the input variables $u_{16.3i}$ and the reference input variables $u_{16.3i0}$. The reference input variables $u_{16.3i0}$ are determined in a basic reference

variable engine characteristic map 16.4 to which the rotational speed n and the fuel quantity m_{fuel} are preferably supplied as input variables.

The input variables $u_{16.3i}$ may preferably include multiple input variables. The input variables $u_{16.3i}$ preferably include a cooling water temperature of the internal combustion engine, a pressure and/or a charge pressure in the intake tract 4 (e.g., at the measurement point 11 in FIG 1), a trigger start of injection, optionally a post-injection, optionally an exhaust gas back pressure, which varies greatly in particular when using a particulate filter in the exhaust gas tract 5, a so-called rail pressure, a temperature of the gas mixture which the gas mixture is measured in the gas mixture in the intake tract after admixture of the recirculated exhaust gas and before entrance into the internal combustion engine and/or a mixed temperature from a previous computation step of the inventive method, preferably the last computation step, and the exhaust gas recirculation rate from a previous computation step of the inventive method, preferably the last computation step. The rail pressure is understood to be the pressure which prevails in diesel engines with a common rail device on the common supply line for fuel to the individual cylinders of the internal combustion engine. Except for the mixed temperature and the exhaust gas recirculation rate, the other input variables $u_{16.3i}$ are preferably in the form of measured values.

The inventive method takes place continuously. In other words, during operation of the internal combustion engine, the actual value for the exhaust gas recirculation rate is determined anew by repeated running, i.e., retrieval of the inventive method and is thus updated in this way. The mixed temperature (calculated in block 14 in FIG 2) and the exhaust gas

recirculation rate of preferably the last computation step and/or the last retrieval of the inventive method preferably form the input variables $u_{16.3i}$ of the correction model 16.3.

The correction model 16.3 includes a corresponding model, preferably an engine characteristic map for each input variable $u_{16.3i}$. Likewise a correction variable $y_{16.3i}$ is determined for each input variable $u_{16.3i}$ by means of the correction model 16.3, thus consisting of a group of models. The correction variable $y_{16.3i}$ is thus a group and/or a vector of correction variables which are added to the preferably static basic exhaust gas temperature $y_{16.1}$ at the coupling point 16.2, forming a corrected exhaust gas temperature $y_{16.2}$, preferably a static temperature. Instead of a summation, a multiplication may also be performed at the coupling point 16.2, if this is advantageous. Thus a correction of the preferably static exhaust gas temperature value $y_{16.1}$ takes place at the coupling point 16.2 when the current operating state, as defined by the input variables $u_{16.3i}$, deviates from a reference state, as defined by the reference input variables $u_{16.3i0}$.

The corrected, preferably static exhaust gas temperature $y_{16.2}$ is filtered in the function block 16.5, forming a current dynamic exhaust gas temperature $T_{exhaust}$. A dynamic correction of the preferably static value $y_{16.2}$ is performed in the filter block 16.5. Since there is usually a heat exchange of exhaust gas with an exhaust gas bend which is typically provided in a motor vehicle, the actual exhaust gas temperature differs from a statically determined exhaust gas temperature $y_{16.2}$. By filtering in the function block 16.5, an approximation of the calculated exhaust gas temperature to the actual exhaust gas temperature can be created.

FIG 5 shows as a block diagram an overall model 17 for determining the temperature of the recirculated exhaust gas, also referred to as the exhaust gas recirculation model. The model corresponds in structure to the fresh gas temperature model 15. With the exhaust gas recirculation model 17, the exhaust gas recirculation temperature, i.e., the temperature of the recirculated exhaust gas T_{AGR} is determined from an exhaust gas temperature $T_{exhaust}$ which represents the output variable of the function block 16 (explained in greater detail with reference to FIG 4), from a mass flow of the recirculated exhaust gas dm_{AGR}/dt, also referred to simply as the exhaust gas recirculation mass flow, and from additional input variables $u_{17.3i}$ that are relevant for the temperature of the recirculated exhaust gas. The input variables u_{17i} of the function block 17 in FIG 2 include the exhaust gas recirculation mass flow dm_{AGR}/dt and the input variables $u_{17.3i}$. The exhaust gas recirculation model 17 is an overall model for the cooling of the recirculated gas by the cooler 9 of the recirculation system 8 (see FIG 1) and includes an exhaust gas recirculation cooler model.

In a basic model 17.1, a basic cooling $y_{17.1}$ is calculated from the exhaust gas temperature $T_{exhaust}$ and the exhaust gas recirculation mass flow dm_{AGR}/dt. This basic cooling corresponds to a basic cooling in a reference state $u_{17.3i0}$. In a correction model 17.3, a correction variable $y_{17.3i}$ for the cooling $y_{17.1}$ is determined from the exhaust gas recirculation mass flow dm_{AGR}/dt and the input variables $u_{17.3i}$. A deviation in the input variables $u_{17.3i}$ from the reference variables and/or initial input variables $u_{17.3i0}$ is taken into account here by means of the correction model 17.3. This deviation is preferably defined as the difference between the input variables $u_{17.3i}$ and the reference input variables $u_{17.3i0}$. Alternatively, it may also be defined as the quotient of

the input variables $u_{17.3i}$ and the reference input variables $u_{17.3i0}$. The reference input variables $u_{17.3i0}$ are determined in advance and preferably entered into a field 17.4 which is in turn preferably saved in a memory area of a control unit.

The input variables $u_{17.3i}$ preferably include a cooling water temperature of the internal combustion engine and/or an ambient temperature. The correction model 17.3 has a separate model for each input variable $u_{17.3i}$. The correction model 17.3 is thus a group of correction models. Likewise, one input variable $y_{17.3i}$ of the correction model 17.3 is assigned to each input variable $u_{17.3i}$. The correction values and/or the correction value $y_{17.3i}$ is/are added to the basic cooling $y_{17.1}$ at a coupling point 17.2 forming a corrected cooling $y_{17.2}$. Instead of an addition, a multiplication may also be performed at the coupling point if this appears advantageous. The corrected cooling $y_{17.2}$ is subtracted from the current exhaust gas temperature at the coupling point 17.6, forming an exhaust gas temperature $y_{17.6}$ that takes into account cooling in the recirculation. The temperature variable $y_{17.6}$ is sent to the filter block 17.5 for dynamic correction to obtain a realistic characteristic in forming the exhaust gas recirculation temperature T_{AGR}. Due to the selected model structure of the exhaust gas recirculation model 17 and the input variables u_{17i} that are used and are relevant for the exhaust gas recirculation temperature, it is possible to reflect the phenomenology of a cooler provided in an exhaust gas recirculation line.

FIG 6 shows a block diagram of an overall model for determination of a volumetric efficiency and/or a volumetric efficiency model 18. In the volumetric efficiency model 18, a volumetric efficiency □ is determined from a

fuel quantity m_{fuel}, a rotational speed of the internal combustion engine n and the input variables $u_{18.3i}$. The input variables $u_{18.i}$ of the function block 18 of FIG 2 include a fuel quantity m_{fuel}, the rotational speed n and the input variables $u_{18.3i}$.

The fuel quantity m_{fuel} is filtered in a filter block 18.5, forming a filtered fuel quantity $y_{18.5}$. The filtered fuel quantity $y_{18.5}$ and the rotational speed n constitute the input variables for a basic model 18.1 which is used for determining a basic volumetric efficiency $y_{18.1}$. The basic model 18.1 is preferably a volumetric efficiency engine characteristic map which spans the rotational speed n and the fuel quantity m_{fuel}, whereby the dependence on the rotational speed n is a flow effect and the dependence on the fuel quantity is thermal effect. To better simulate this thermal effect, the fuel quantity m_{fuel} is filtered in the filter block 18.5, preferably before being entered into the basic model 18.1. The filtering is preferably performed by a first-order delay element. The basic volumetric efficiency $y_{18.1}$ is corrected by means of a correction value $y_{18.3i}$ at a coupling point 18.2. In forming the correction value and/or the correction values $y_{18.3i}$ the deviation in the input variables $u_{18.3i}$ from the predefined reference states and/or initial states and/or reference input variables $u_{18.3i0}$ is taken into account. This deviation is preferably defined as the difference between the input variables $u_{18.3i}$ and the initial variables $u_{18.3i0}$. The reference input variables $u_{18.3i0}$ are preferably determined in a reference variable model 18.4 which has the rotational speed n and the fuel quantity m_{fuel} as input variables. The reference variable model 18.4 is preferably an engine characteristic map which covers the fuel quantity m_{fuel} and the rotational speed n.

The input variables $u_{18.3i}$ preferably include a cooling water temperature of the internal combustion engine and a mixed temperature which has been determined in the function block 14 of FIG 2 in a previous computation step, preferably the last computation step, of the inventive method. The mixed temperature is the temperature of the gas mixture after admixture of recirculated exhaust gas but before entering the intake tract 4 (see FIG 1) into the internal combustion engine. The mixed temperature as well as the cooling water temperature constitute a thermal influence of the volumetric efficiency because the volumetric efficiency represents the ratio of the real quantity of fresh gas in a cylinder of the internal combustion engine to the quantity of fresh gas theoretically possible based on a reference location, preferably the mixing site of fresh gas, i.e., fresh air and recycled exhaust gas. The real quantity of gas mixture is influenced by the flow losses between the mixing site and the cylinder, by heating and/or cooling of the gas mixture due to surrounding components. The heating and/or cooling of the gas mixture due to the surrounding components leads to a loss of density or to an increase in density of the gas mixture.

The correction model 18.3 includes one model and/or one engine characteristic map per input variable $u_{18.3i}$. Likewise, each input variable $u_{18.3i}$ is assigned an output variable and/or a correction value $y_{18.3i}$. The correction value(s) $y_{18.3i}$ is (are) added to the basic volumetric efficiency $y_{18.1}$ at a coupling point 18.2, forming the current volumetric efficiency □. The coupling point 18.2 may also be a multiplication point if this appears advantageous.

In the volumetric efficiency model 18, the current volumetric efficiency is calculated on the basis of a basic volumetric efficiency $y_{18.1}$. Alternatively, the current volumetric efficiency □ can also be calculated on the basis of the volumet $\dot{m}_{air}$ ""iciency equation mentioned above

$$\eta = \frac{m_{Luft} \cdot T \cdot R}{p \cdot V_h}$$

from the fresh gas quantity m_{air}, the charging pressure p and the fresh gas temperature T as variables, where R is the individual gas constant and V_h is the displacement of the internal combustion engine. The calculation methods are mathematically equivalent. The calculation starting from a basic volumetric efficiency offers the advantage that only one value, namely the volumetric efficiency, need be corrected when there is a deviation from the reference state instead of having to correct three values (pressure, temperature and fresh gas quantity).

Patent Claims

1. Method for determining the exhaust gas recirculation quantity for an internal combustion engine having exhaust gas recirculation, characterized in that the exhaust gas recirculation quantity (r_{AGR}, m_{AGR}) is determined from an exhaust gas temperature ($T_{exhaust}$), from a fresh gas temperature (T_{air2}), from a fresh gas quantity (m_{air}) and/or a volumetric efficiency (□), and the fresh gas temperature (T_{air2}) is determined by a fresh gas temperature model (15) which is adaptively adapted to influencing parameters relevant to the fresh gas temperature.